Observation and Numerical Simulation of Propagation of ULF Waves From the Ion Foreshock Into the Magnetosphere

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Observational studies have demonstrated that ULF waves excited in the ion foreshock are a main source of Pc3-4 ULF waves detected in the magnetosphere. However, quantitative understanding of the propagation of the waves is not easy, because the waves are generated through a kinetic process in the foreshock, pass through the turbulent magnetosheath, and propagate as fast mode waves and couple to shear Alfvén waves within the magnetosphere. Recent advancement of hybrid numerical simulations of foreshock dynamics motivated us to analyze observational data from multiple sources and compare the results with simulation results. We have selected the time interval 1000-1200 UT on 20 July 2016, when the THEMIS, GOES, and Van Allen Probe spacecraft covered the solar wind, foreshock, magnetosheath, and magnetosphere. The EMMA magnetometers (L=1.6-6.5) were located near noon. We found that the spectrum of the magnetic field magnitude (Bt) in the foreshock exhibits a peak near 90 mHz, which agrees with the theoretical prediction assuming an ion beam instability in the foreshock. A similar Bt spectrum is found in the dayside outer magnetosphere but not in the magnetosheath or in the nightside magnetosphere. On the ground, a 90 mHz spectral peak was detected in the H component only at L=2-3. The numerical simulation using the VLASIATOR code shows that the foreshock is formed on the prenoon sector but that the effect of the upstream waves in the magnetosphere is most pronounced at noon. The Bt spectrum of the simulated waves in the outer magnetosphere exhibits a peak at 90 mHz, which is consistent with the observation.
